ARL-SR-0416 • MAY 2019

US Army Combat Capabilities Development Command Army Research Laboratory South Research Summaries: Open Campus Collaborations

by Heidi Maupin

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ARL-SR-0416 ● MAY 2019

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
May 2019	Special Report	1 April 2017–29 April 2019

4. TITLE AND SUBTITLE
US Army Combat Capabilities Development Command Army Research Laboratory South Research Summaries: Open Campus Collaborations

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Heidi Maupin

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Combat Capabilities Development Command, Army Research Laboratory
ATTN: FCDD-RLD
Aberdeen Proving Ground, MD 21005

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-SR-0416

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This document highlights the collaborative research efforts resulting from the US Army Combat Capabilities Development Command (CCDC) Army Research Laboratory's (ARL's) Open Campus initiative. The ARL South research summarized in this document is integral to the CCDC ARL overarching research strategy; each project is a component of one or more of ARL's essential research programs. While ARL's research primarily falls in the basic research arena with projected longer-term transitions, critical shorter-term outcomes will be recognized and exploited along the way. The research summaries include current technical readiness levels (TRLs), and in some cases identify the time it will take to reach TRL 6.

15. SUBJECT TERMS
Open Campus, collaborative research, Army Research Laboratory, South Region, basic Army research

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Heidi Maupin
Unclassified	Unclassified	Unclassified	UU	29	19b. TELEPHONE NUMBER (Include area code) 512-232-1634

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1. Introduction

In April 2017, the US Army Combat Capabilities Development Command, Army Research Laboratory (CCDC ARL) extended its geographical presence to the southern region of the United States, centered in Austin, Texas. "ARL South," as it is colloquially called, grew from two to over 100 researchers embedded within 13 research organizations, mostly in the state of Texas, with member connections reaching out to New Mexico, Oklahoma, Alabama, and Pennsylvania. Through strategic collaborative efforts, ARL joined forces with the region's partners to identify areas of mutual technical interest resulting in an environment that fosters innovation, rapid development, and accelerated technology transitions. Army researchers selected partners by identifying research organizations with expertise to complement and augment Army in-house expertise.

The ARL South research summarized in this document is integral to the ARL overarching research strategy; each project is a component of one or more of ARL's essential research programs. While ARL's research primarily falls in the basic research arena with projected longer-term transitions, critical shorter-term outcomes will be recognized and exploited along the way. The research summaries include current technical readiness levels (TRLs), and in some cases identify the time it will take to reach TRL 6.

This document highlights the collaborative research efforts resulting from ARL's Open Campus initiative. Not included in this document are many other excellent research efforts funded by the ARL Directorates and the ARL-Army Research Office.

2. ARL South Research Summaries

2.1 Army Medical Department Center and School

Title: Improved Human Performance

Modernization Priority: Soldier Lethality

Army Researcher: Valerie Rice, Gary Boykin (both onsite)

Directorate: Human Research and Engineering Directorate (HRED)

Summary of Research: Our investigations to improve performance have already shown that Soldiers participating in an effective mindfulness program will increase resilience, improve awareness, and decrease the effects of post-traumatic stress

disorder and adult deficit hyperactivity disorder. The following three studies are underway: 1) Measuring performance improvement through Mindfulness-Based Stress Reduction. 2) Examining the effects of a neuromodulator for improved balance/equilibrium and improved memory and ability to learn and retain information from patients who have been treated for equilibrium issues (MS, brain injury, stroke, car accident, etc.). Exposed pulse directed energies are being tested on animals during the current phase of the research. 3) Developing a trans-cranial magnetic stimulation to measure resilience and applying to a military environment for operational relevancy. Our research is focused on issues of interest to ARL and to the Army Medical Department Center and School and the Army Medical Command.

2.2 Rice University

Title: Dynamic Optical Control via Metasurface Integrated Soft Robotic Skins

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: Mark Griep

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POCs: Stephan Link, Ben Cerjan

Summary of Research: The goal of this project is to produce a flexible color-changing surface that could be used as a "skin" on a given object and therefore be used as camouflage or a "cloaking" tool. To do this, we are using a combination of the expertise at Rice (and the University of New Mexico) in design and fabrication of nanostructures and metasurfaces, along with the knowledge and experience in nanoimprint lithography and roll-to-roll scale up at ARL. Previous work at Rice has demonstrated two complementary approaches to this challenge: First, by designing a "plasmonic pixel" that interacts in the far-field (like a diffraction grating) consisting of an array of metallic nanoparticles with finely tuned size and periodicity to produce the desired color. Second, by designing more complex individual structures which, due to the near-field interaction between different parts of the structure, produce a strong color. Either of these methodologies could work on their own as both are highly sensitive to the geometric distance between neighboring elements and so by placing them on a stretchable substrate, the color response can be directly tuned by mechanical deformation.

TRL Level: 1

Title: Responsive Materials with Active Subunits

Modernization Priority: Future Vertical Lift, Next Generation Ground Vehicle

Army Researcher: Frank Gardea (onsite)

Directorate: Vehicle Technology Directorate (VTD)

Faculty POC: James Tour (Rice)

Summary of Research: Our research results will be used to provide an efficient power source for autonomous vehicles by mimicking behavior found in nature. This research focuses on embedding active molecular units in polymer systems to achieve behavior and actuation similar to what is observed in biological muscle. These active subunits will be manipulated to achieve dynamically reconfigurable structures at the macroscale. This approach is expected to lead to highly multifunctional structures. Synthetically reproducing biological type adaptation enabled by molecular machinery could enable efficient, highly adaptive reflexive mobility observed in biological systems.

TRL Level: 1

Anticipated time to TRL Level 6: 6–10 years

Title: Seek and Treat UAV Technologies for Combat Casualty Care

Modernization Priority: Future Vertical Lift

Army Researcher: Thaddeus P Thomas

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POC: Paul Cherukuri

Summary of Research: The goal for this effort is to make Robotic and Autonomous Systems (RAS) more intelligent and capable in the medical treatment of military personnel. We are incorporating novel imaging technologies that measure physiology at range onto unmanned mobile platforms to support the remote identification and triage of battlefield casualties. This capability would enhance the speed and effectiveness of medical evacuation/triage crews, and improve the likelihood of patient survival. Biosensor advancement and assessment tasks are being conducted at Rice University, ARL, and the US Army Medical Research Institute of Chemical Defense. The University of Pittsburgh contributes medical expertise and Carnegie Mellon University is building robotic interventions

and researching means for providing virtual help. The work is projected to be complete within a one-year time frame.

TRL Level 5: There are components of the concept that are high TRL, but the overall package is at a 2.

Anticipated time to TRL Level 6: With additional resources, progress could be accelerated to easily meet a 2020 timeline.

Title: Directed Energy Bio Effects

Modernization Priority: Soldier Lethality

Army Researcher: Thaddeus P Thomas, Ben Kasukonis (Tri-Service Research Lab onsite)

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POCs: Ron Poropatich (U Pitt), Paul Cherukuri (Rice)

Summary of Research: US government personnel are at risk for surprise and severe injury by the adversary's exploitation of Directed Energy (DE) biological effects. Our research is focused on characterizing the threat of novel DE weapon systems to personnel. Knowledge from the basic and applied research is being transitioned for developing effective medical and materiel countermeasures. This tri-service and interagency effort leverages resources throughout the US government and academia.

TRL Level: 2

2.3 Texas A&M University

Title: Spanwise Extending Unmanned Aerial Systems

Modernization Priority: Future Vertical Lift, Next Generation Combat Vehicle

Army Researcher: Francis Phillips (onsite)

Directorate: Vehicle Technology Directorate (VTD)

Faculty POC: Darren Hartl

Summary of Research: This research advances capability of aerial systems and enables them to modify structure to respond to current situational needs. ARL is developing a spanwise extending small unmanned aerial system (sUAS). The

concept sUAS will be able to actively change the span of the wings in response to mission profile, environmental conditions, and Soldier/vehicle command. We are leveraging Texas A&M's active materials expertise to develop active internal wing structure to enable the spanwise extension.

TRL Level: 2

Anticipated time to TRL Level 6: 6 years

Title: Tube Launched Attritable Unmanned Aerial Systems

Modernization Priority: Future Vertical Lift

Army Researcher: Hao Kang

Directorate: Vehicle Technology Directorate (VTD)

Faculty POC: Moble Benedict

Summary of Research: ARL and Texas A&M are collaborating on technologies to enable and advance capability for a tube (air and ground) launched, potentially attritable unmanned aerial system (UAS) weighing up to 50 lb. Areas of research include high performance platform concept development and UAS control and stability. In addition to the tube-launched UAS, there are efforts to develop analytical powertrain models for small UAS as part of an effort to rapidly deliver mission-customized small UAS to the battlefield.

TRL Level: 4

Anticipated time to TRL Level 6: 1 year

Title: High-Pressure Compact Turbochargers

Modernization Priority: Future Vertical Lift

Army Researcher: Mike Kweon

Directorate: Vehicle Technology Directorate (VTD)

Faculty POC: Luis San Andres (Joint Faculty Appointment)

Summary of Research: ARL and Texas A&M are collaborating on high-pressure compact turbochargers to support ARL's multi-fuel capable hybrid electric propulsion program. The project aims to advance innovative gas bearing technologies enabling oil-free turbochargers (TCs) for ultra-efficient propulsion Internal Combustion Engines (ICEs) in unmanned aerial vehicles (UAVs). These

oil-free TCs will improve the reliability, efficiency, and performance of ICEs for operation at higher speeds with more compact units free of mineral oil and other ancillary systems. Further benefits of oil-free TCs include reductions in weight and drag, extended maintenance intervals, and certified reliability and availability.

TRL Level: 3

Anticipated time to TRL Level 6: 5 years

Title: Human-in-the-Loop Autonomy

Modernization Priority: Future Vertical Lift, Next Generation Combat Vehicle

Army Researchers: Vernon Lawhern, Nicholas Waytowich, Greg Gremillion

Directorate: Human Research Engineering Directorate (HRED)

Faculty POC: John Valasek

Summary of Research: Texas A&M is working with ARL on human-in-the-loop machine learning for autonomy with specific applications in real and simulated aerial platforms. By more tightly integrating a human operator into the learning process, autonomous agents learn faster and the learned behaviors can become tailored to the specific needs of the Warfighter.

TRL Level: 2

Anticipated time to TRL Level 6: 5 years

Title: Monolithic Tungsten for Kinetic Energy Munitions

Modernization Priority: Soldier Lethality

Open Campus Army Research Collaborators: ARL/Texas A&M/Shearform

Army Researcher: Brady Butler, James Paramore (both onsite)

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POC: Ted Hartwig (Shearform)

Summary of Research: New processing technique by Texas A&M spin-off company Shearform produces tungsten with properties that when used to manufacture medium and long-range penetrators will surpass the performance of current penetrators, achieving oblique angle penetration.

TRL Level: 3

Anticipated time to TRL Level 6: 3 years

Title: Hydrogen Assisted Processing of Ti-6Al-4V

Modernization Priorities: Soldier Lethality

Army Researchers: James Paramore and Brady Butler (both onsite)

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POC: Ankit Srivestava

Summary of Research: This project targets Next Generation Squad Weapon Technologies. We are developing processes to produce low cost titanium that exhibits equivalent properties to conventionally manufactured high-grade titanium alloys. Titanium is a material of interest that could be used for replacement parts at the point of need; this process will be cost effective for point of need part production. The research is being combined with near-net-shaping and additive manufacturing (AM) process technologies for prototyping titanium alloy components with exceptional mechanical properties.

TRL Level: 4

Anticipated time to TRL Level 6: 1 year

Title: Adaptive Material Behavior

Modernization Priority: Future Vertical Lift, Next Generation Combat Vehicle

Army Researcher: Frank Gardea (onsite)

Directorate: Vehicle Technology Directorate (VTD)

Faculty POCs: Svetlana Sukhishvili, Mohamad Naraghi

Summary of Research: Our advanced materials will contribute to a sophisticated vehicle protection that will sense and adapt to current threats. We strive for on-demand tailoring of material properties (i.e., high strength, high stiffness, and high energy dissipation) and functionalities (e.g., self-healing, actuation, wave manipulation) to achieve adaptive behavior in materials. We utilize advanced manufacturing methods, such as AM, to obtain properties that are unobtainable using conventional manufacturing.

TRL Level: 1

Anticipated time to TRL Level 6: 6–10 years

Title: Programmable Three-dimensional Metamaterials

Modernization Priority: Next Generation Combat Vehicle, Future Vertical Lift

Army Researcher: Frank Gardea (onsite)

Directorate: Vehicle Technology Directorate (VTD)

University POC: Ibrahim Karaman

Summary of Research: The advanced materials obtained through this research will result in capability for structures to sense and respond to current threats. This project deals with the design, optimization, and realization of programmable 3-D metamaterials for steering mechanical waves in arbitrary directions. The realized metamaterials will enable functional tenability on the unit-cell level. These materials will work as a stepping-stone toward the next generation of autonomous functional metamaterials and structures.

Current TRL Level: 1

Title: Compact, High Performance Electric Machines Using Magnetic Gears

Modernization Priorities: Future Vertical Lift, Sustainability, Next Generation Combat Vehicle

Army Researcher: Matthew Johnson (onsite)

Directorate: Sensors and Electron Devices Directorate (SEDD)

Faculty POC: Hamid Toliyat

Summary of Research: This research focuses on the design of compact, high performance, and high reliability electric machines and magnetic gears for Army platform drivetrains, including hybrid electric aircraft and UAVs. We will reduce the size and weight of magnetic gears, while enabling them to achieve higher gear ratios and operating speeds without sacrificing high efficiencies. The non-contact operation offers numerous potential advantages over traditional mechanical gears, including inherent overload protection, reduced maintenance requirements, decreased acoustic noise, and physical isolation between the input and output shafts.

TRL Level: 3

Anticipated time to TRL Level 6: 6 years

Title: Multi-Scale Mechanics of Lung During Blunt Trauma: Alveolar Sacs to/from Parenchyma

Modernization Priority: Soldier Lethality

Army Researcher: John D Clayton

Directorate: Weapons and Materials Research Directorate (WMRD)

University POC: Alan D Freed (Joint Faculty Appointment)

Summary of Research: Soldiers are placed at risk of incurring Behind Armor Blunt Trauma (BABT) on a field of battle whenever their Personal Protective Equipment (PPE) suffers a ballistic impact from a weapon or blast wave from an explosion. The objective of this project is to provide design engineers a realistic tool to produce the next generation of PPE for our Soldiers. We will develop material models that will be capable of describing soft tissue responses under ballistic impact conditions. Our multiscale models will predict lung tissue damage that affects breathing from tissue stiffness and internal bleeding.

Current TRL Level: 1

2.4 Texas Tech University

Title: Machine Learning Technique Applications for Power Electronic Systems

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: Argenis Bilbao (onsite)

Directorate: Sensors and Electron Devices Directorate (SEDD)

Faculty POC: Stephen Bayne

Summary of Research: ARL is investigating the currently available machine learning techniques for implementation in power electronic converters. This research is subdivided in multiple application levels: machine learning at the power distribution, power converter, and semiconductor module levels. The use of machine learning at the aforementioned levels will provide significant improvements in reliability and overall system capabilities.

TRL Level: 2

Anticipated time to TRL Level 6: 6 years

Title: Wireless Power Transfer for Unmanned Aerial Vehicles

Modernization Priority: Future Vertical Lift

Army Researcher: Argenis Bilbao

Directorate: Sensors and Electron Devices Directorate (SEDD)

Faculty POC: Stephen Bayne

Summary of Research: We are performing research on wireless power transfer to efficiently recharge UAVs. Wireless power transfer is the ideal and primary candidate to recharge battery powered UAVs due to the increased reliability, convenience, and reduced logistics burden that it provides over recharging through wires using metallic contacts.

TRL Level: 3

Anticipated time to TRL Level 6: 6 years

2.5 University of New Mexico

Title: Studying Human Agent Teaming Through Games

Modernization Priority: Next Generation Ground Combat

Army Researcher: Evan Carter (onsite)

Directorate: Human Research and Engineering Directorate (HRED)

Faculty POCs: Lydia Tapia and James Cavanagh

Summary of Research: The study of human agent teaming is complicated by the fact that there is immense variation both between and within individuals. As a result, it is difficult to design agents to be optimal teammates for any given user at any given time. Our goal is to develop adaptive agents based on large data sets collected through mobile games that can be played by many people throughout their daily lives, thereby better accounting for between- and within-person variability.

TRL Level: 1

Anticipated time to TRL Level 6: 5 years

2.6 University of North Texas

Title: Design of Novel Metals, Ceramics, and Additively Manufactured Structures for Protection Applications

Modernization Priority: Next Generation Combat Vehicle

Army Researchers: Jeff Lloyd, Chris Cummins

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POC: Rajiv Mishra

Summary of Research: We are producing novel materials (e.g., high entropy alloys, ceramics) having lighter and/or ultra-high toughness to enhance vehicle protection and efficiency. In addition to our materials research, we are designing additively manufactured structures that will dramatically increase vehicle protection and durability. We have demonstrated that small-scale prototypes produced using AM techniques are representative of the full-scale vehicle structure. Using our validated results that reduce assessment time from years to weeks will rapidly provide new solutions for blast resistant structures, and reduce research and development costs by 98%. Furthermore, our small-scale experimentation enables an indoor laboratory environment, eliminating scheduling risks arising from weather constraints and significantly reducing the risk of damage to sensitive instrumentation.

TRL Level: 2

Anticipated time to TRL Level 6: 5–10 years

Title: Modulate Mechanical Properties under Applied Magnetic Fields

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: Heather Murdoch

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POC: Rajiv Mishra

Summary of Research: This advanced materials research will result in greatly improved lightweight vehicle and Soldier protection. We will identify changes in mechanical behavior under applied magnetic fields, particularly relating to deformation processing of lightweight (paramagnetic) metals (e.g., aluminum and magnesium alloys). We have observed shifts in yield under low fields in aluminum alloys and thus have developed a robust testing frame incorporating variations in

magnetic field strength to investigate tension, compression, and fatigue. We will identify magnetic property characterization of Army-relevant alloys for use in magnetic processing model development.

TRL Level: 1–2

Anticipated time to TRL Level 6: 5–10 years

Title: Magnetic Freeze Casting of Ceramic Structures

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: Raymond Brennan

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POCs: Marcus Young, Samir Aouadi, Diana Berman

Summary of Research: We are pursuing an advanced ceramic material that will provide a lightweight armor protection for vehicles. ARL is collaborating on a two-step task for generating porous ceramic structures via magnetic freeze casting, followed by secondary phase/material infiltration to form dense bulk composites capable of sustaining high strain rates.

TRL Level: 2

Anticipated time to TRL Level 6: 5–10 years

2.7 University of Texas at Arlington

Title: Human Dynamics of Cyber Security

Modernization Priority: Soldier Lethality

Army Researchers: Laura Marusich (onsite), Jonathan Bakdash (UT Dallas)

Directorate: Human Research and Engineering Directorate (HRED)

Faculty POCs: Paul Paulus, Jared Kenworthy, Gautam Das, Chengkai Li, Kay-Yut Chen, Jingguo Wang

Summary of Research: We are engaged in several lines of research focused on the human element of cybersecurity. One line of research focuses on effective team formation and collaboration, with a specific application to cyber defense teams. Another project takes a behavioral game theory perspective, focusing on modeling cyber warfare as an attacker-defender game. A third line of research focuses on

developing predictive models of cyber-attacks, using time-series forecasting and other techniques.

TRL Level: 2–3

Anticipated time to TRL Level 6: 5–10 years

2.8 University of Texas at Austin

Title: Army Research Lab (ARL)/UT Austin/Uber Stacked Co-axial Rotor for Quieter Vertical Lift Air Vehicles

Modernization Priority: Future Vertical Lift

Army Researcher: Rajneesh Singh

Collaborators: Uber/UT Austin/ ARL

Directorate: Vehicle Technology Directorate (VTD)

Faculty POC: Jayant Sirohi

Summary of Research: ARL and UT Austin are investigating an innovative rotor concept to enable quieter operations of vertical lift. We are conducting experiments to measure aeromechanics performance and noise characteristics of the stacked coaxial rotor to evaluate feasibility of using it for UAVs and manned air taxi operations. This effort is part of the ARL/Uber cooperative research and development agreement (CRADA) and part of the research at UT Austin is funded by Uber.

TRL Level: 3

Anticipated time to TRL Level 6: 3 years

Title: Human-in-the-Loop Autonomy

Modernization Priority: Next Generation Combat Vehicle

Army Researchers: Garrett Warnell (onsite)

Directorate: Computational and Information Sciences Directorate (CISD)

Faculty POCs: Peter Stone (Professor, UT Austin)

Summary of Research: By studying and developing methods that can more tightly integrate human operators into autonomous systems, future artificial agents can be more effective and exhibit faster adaptation to new environments. ARL is

partnering with the University of Texas at Austin to perform basic research on human-in-the-loop autonomy for a variety of simulated (early-stage research) and physical (mid- to late-stage research) autonomous systems. Multiple modalities of human input—including passive (e.g., video) and explicit (e.g., teleop) demonstration and feedback—are being studied for the purposes of enhancing human control of robotic systems, increasing the efficacy of autonomous behaviors, and increasing the speed of autonomous behavior acquisition. New methods for sharing control of platforms between humans and artificial agents in teleop-like control scenarios are being developed and validated, and new machine learning algorithms that seek to allow non-expert humans to teach new behaviors to artificial agents are also being developed and validated. One project seeks to extend classical imitation learning methods such that future autonomous agents can learn new behaviors directly from video demonstrations (e.g., YouTube videos).

TRL Level: 2

Anticipated time to TRL Level 6: 4 years

Title: Pareto Optimal Streaming Unsupervised Classification for Human-Autonomy Interaction for Intelligent Squad Weapons (HAI2SW)

Modernization Priorities: Soldier Lethality

Army Researcher: Brent Lance, Steven Gutstein

Directorate: Human Research and Engineering Directorate (HRED)

Faculty POC: Sanjay Shakkotai

Summary of Research: We will advance the ability of autonomous classification of data gathered to accurately identify and respond to detected objects through improved theoretical optimal limits on throughput and accuracy for an unsupervised ensemble of machine learning classifiers. By applying these resulting adaptive training methods to label training sets obtained through opportunistically collected data generated as a result of Soldier actions, we will provide dismounted Soldiers with advanced target acquisition capabilities.

TRL Level: 1

Anticipated time to TRL Level 6: 7 years

Title: Synthetic Biology

Modernization Priority: Soldier Lethality

Army Researchers: Jimmy Gollihar (onsite)

Directorate: Sensors and Electron Devices Directorate (SEDD)

Faculty POCs: Schonna R Manning (Joint Faculty Appointment), Andrew Ellington

Summary of Research: We are equipping a unique, government owned, secure synthetic biology foundry. By building advanced manufacturing capability, we will be able to synthesize and assemble a wide variety of biological constructs that will be of utility across the Army and the Department of Defense. The multi-domain capabilities we aim to achieve include rapid response/medical countermeasures, biomaterial development and deployment, and advanced sensor and Signature Management methods. Examples of intended outcomes are advanced optical materials, new biomaterials leading to a generation of hard-soft robots to ease interaction with humans, and synthetic circuits for metabolic regulation for novel biological sensor platforms. We plan to implement rapid response medical countermeasures for improved human performance as well as interventions against chemical, biological, and environmental insults.

TRL Level: 2

Title: Large-Scale Multiphysics Modeling and Simulation for Advanced Electronic and Electromechanical Systems

Modernization Priority: Next Generation Combat Vehicle

Army Collaborator: Bruce Geil

Directorate: Sensors and Electron Devices Directorate (SEDD)

Faculty POCs: Shannon Strank (Joint Faculty Appointment), Vaibhav Bahadur, Hamid Ouroua

Summary of Research: Technology advancements discovered through this project will revolutionize power capabilities. The final electronics package will include advanced materials robust enough to withstand extreme conditions, including electrical frequencies, and thermal and mechanical cycles. Critical to our success is a multi-physics model that will predict behavior of the designed package, and will be used to evaluate innovative material selection for the power package. We will maximize performance gains garnered by emerging dielectric materials, new packaging techniques (including 3-D printing), and various power packaging applications.

TRL Level: 2

Title: Additive Materials Processing for Novel Army System Development

Modernization Priority: Next Generation Combat Vehicle

Army Researchers: Erich Bain, Daniel Galles

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POC: Joseph Beaman

Summary of Research: We aim to use selective laser sintering (additive manufacturing) to produce high quality thermoplastic material that can withstand extremely high temperatures. This material property is essential to deliver power supply needed for advanced Army applications.

TRL Level: 4–5

Anticipated time to TRL Level 6: 1 year

Title: Aerosol Deposition of Metal and Ceramic Powders

Modernization Priority: Long Range Precision Fires

Army Researcher: Michael Gammage (onsite)

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POC: Desi Kovar

Summary of Research: The purpose for this research is to reduce weight and volume needed for electronics and increase the volume available for payload and propulsion. We are developing a new technique to complement current additive manufactured electronics technologies. With this technique we can print electronics into structural parts and antennae on conformal surfaces.

TRL Level: 3

Anticipated time to TRL Level 6: 6 years

Title: Aluminum-Based Nanogalvanic Powder Materials for Hydrogen Fuel

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: Anit Giri

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POC: Michael Lewis

Summary of Research: Our low-cost material (US patent publication #20190024216A1/January 24, 2019) promises to deliver a safe and reliable mechanism for storing and provisioning hydrogen to a fuel cell power system. This type of solution can be helpful in multiple mission scenarios where hydrogen is scarce. The powder has been shown to react with even the smallest amount of liquid to form hydrogen. The first case will consider cannibalizing a part of the vehicle for immediate limp home power. The second case will consider strategic power plants fueled by this powder dropped near any body of water for refueling of drones.

TRL Level: 1

Anticipated time to TRL Level 6: 5 years

2.9 University of Texas at Dallas

Title: Adversarial Machine Learning

Modernization Priority: Cyber Security/Army Network (Network Command, Control, Communications and Intelligence).

Army Researchers: Jonathan Bakdash (onsite), Laura Marusich (at UT Arlington)

Directorate: Human Research Engineering Directorate (HRED)

Faculty POCs: Murat Kantarcioglu (UT Dallas), Daniel Krawczyk (UT Dallas)

Summary of Research: Research has potential implications for deception in the physical and cyber world, which is pertinent to intelligence analysis. We are conducting research on augmenting detection of deception using multiple approaches, which include machine learning classification of deception, enhanced detection of deception using neuroscience, and time-limited presentation of deceptive materials in behavioral experiments (paradoxically, detection of deception may be better with less information).

TRL Level: 3

Anticipated time to TRL Level 6: Less than 5 years

Title: Fermenting Vegetation for Efficiently Running Artificial Muscle

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: David Mackie

Directorate: Sensors and Electron Devices Directorate (SEDD)

Faculty POC: Ray Baughman

Summary of Research: Our desired outcome is to power artificial muscles using direct conversion of energetic chemicals. This capability will contribute to our overarching goal of an efficiently powered autonomous robotic mule. To date, we have demonstrated chemically powered artificial muscles with excellent performance. Our challenge is to scale up the size by several orders of magnitude in order to achieve chemically powered artificial muscles suitable for the legs of robotic mules. In the first year, we have shown that fuel cells work in an alternating current (AC) mode, and AC fuel cells will be fast enough for our applications. We have shown that we can make affordable chemically powered artificial muscles that are scalable and work well, with speed being the key challenge to overcome.

TRL Level: 1

Anticipated time to TRL Level 6: 5 years

2.10 University of Texas at El Paso

Title: Holistic Cybersecurity Network Analysis

Modernization Priorities: Network/C3I, Sustainability

Army Researcher: Jaime C Acosta (onsite)

Directorate: Computational and Information Sciences Directorate (CISD)

Faculty POC: Salamah Salamah

Summary of Research: ARL and UTEP are collaborating through several vehicles including coursework and leveraging National Science Foundation/Department of Homeland Security designated scholarship for service students as part of the ARL South cybersecurity rapid innovation group (CyberRIG), consisting of cybersecurity professionals, faculty, and students. The collaboration has yielded software and hardware infrastructures and a rapid workflow that focuses on the holistic (attack, operator, defender) perspective of cybersecurity. This work is already being used to develop cybersecurity scenarios, data, and models for

automated network analysis, communication, and defense in next-generation, heterogeneous, network configurations.

TRL Level: 4

Anticipated time to TRL Level 6: 3 years

Title: Additive Manufacturing Development and Analysis

Modernization Priority: Sustainability

Army Researcher: Marc Pepi

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POC: Raymond Rumpf, Francisco Medina

Summary of Research: Our research will accelerate and advance manufacturing readiness of metal AM technology. We focus on rapid AM alloy development, new AM strategies for repair using electron beam melting (EBM) technology, and AM process qualification and verification using powder bed monitoring technology. In addition, our goal is to develop and characterize 3-D antennas for high g applications. We identify and experiment with new materials, and optimize performance through our design approaches to produce and mature materials that will survive high g.

TRL Level: 2

Anticipated time to TRL Level 6: 5 years

2.11 University of Texas at San Antonio

Title: Modeling, Analyzing and Predicting Cyber Attacks

Modernization Priority: Network/C3I

Army Researcher: Ray Bateman and Kristin Schweitzer (both onsite)

Directorate: Computational and Information Sciences Directorate/Human Research and Engineering Directorate (CISD/HRED)

Faculty POC: Shouhuai Xu

Summary of Research: This research uses a three-pronged, statistics-based approach to characterize and analyze cyber-attacks. The areas of research focus include Modeling and Characterizing Cyber Attack Reconnaissance

Tactics/Signatures, Modeling and Characterizing Attack Signatures in the Entire Attack Lifecycle, and Cyber Attack Burstiness and Long Memory for Predictive Situational Awareness.

TRL Level: 1

Anticipated time to TRL Level 6: 3 years

Title: Legged Control Theory

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: Jason Pusey

Directorate: Vehicle Technology Directorate (VTD)

Faculty POC: Pranav Bhounsule

Summary of Research: Robots on legs and with small feet (similar to human morphology) are more suited for missions that involve terrains with limited footholds, stairs, and marshy areas. Stabilizing such systems is challenging not only because of the limited control authority provided by the small feet but also because of the complex dynamics. In the collaboration between UTSA and ARL, we develop a control framework to create highly stable locomotion gaits. Our method involves using optimization to generate control commands for different perturbations. Then the data are mined using deep learning to create stable controllers. These controllers are then verified using extensive stability tests. Our approach is generic and can be applied to robots with multiple legs and multiple gaits, and the computations that we have already developed are much quicker than current state-of-the-art approaches.

TRL Level: 1

Anticipated time to TRL Level 6: 6 years

3. Conclusion

Progress continues in our research areas at a quick pace, and we will publish updates regularly. Collaboration through ARL Open Campus is an essential component in the Army's strategy to maintain global cutting edge technical dominance.

List of Symbols, Abbreviations, and Acronyms

3-D	three-dimensional
AM	additive manufacturing
ARL	Army Research Laboratory
BABT	Behind Armor Blunt Trauma
CCDC	US Army Combat Capabilities Development Command
CISD	Computational and Information Sciences Directorate
CRADA	cooperative research and development agreement
CyberRIG	cybersecurity rapid innovation group
DE	Directed Energy
EBM	electron beam melting
HRED	Human Research and Engineering Directorate
ICE	internal combustion engine
PPE	Personal Protective Equipment
RAS	Robotic and Autonomous Systems
SEDD	Sensors and Electron Devices Directorate
sUAS	small unmanned aerial system
TRL	technical readiness level
UAV	unmanned aerial vehicle
VTD	Vehicle Technology Directorate
WMRD	Weapons and Materials Research Directorate

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J ALEXANDER
W BENARD
M HIGGINS
K KRAPELS
C REESE
R DEL ROSARIO
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E SHAFFER
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J SUMNER
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